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UTAH JUNIPER IN CENTRAL ARIZONA.

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CONTENTS.

	Page.
Purpose of the study	3
Distribution	3
Climatic requirements	4
Botanical characteristics	4
Silvical characteristics	5
Site requirements and associated species	5
Stem and crown	6
Root system	7
Reproduction	7
Injuries	8
Fungi and mistletoe	8
Fire	9
Sheep and cattle	10
Growth	10
Volume	12
Construction and use of volume tables	12
Volume in cubic feet and cords	14
Supplementary tables	15
Yield	18
Utilization	18
Management	19

ILLUSTRATIONS.

PLATES.

	Page.
PLATE I. Fig. 1—A Utah juniper forking at breastheight. Fig. 2—Virgin stand of Utah juniper. Fig. 3—Irregularity of Utah juniper cordwood	8
II. Fig. 1—A two-stemmed Utah juniper considered as a single tree. Fig. 2—A three-stemmed tree	12

TEXT FIGURE.

FIG. 1—Utah juniper—leaves, fruit, and seed	4

UTAH JUNIPER IN CENTRAL ARIZONA.

PURPOSE OF THE STUDY.

Utah juniper (*Juniperus utahensis*) is the most important tree in the woodland forest of central Arizona. The woodland forest itself is of value chiefly because the scarcity of timber in the region of its occurrence brings its products into great demand for fuel, fence posts, and other small but important uses. Hitherto it has commonly been known as the woodland type—a misuse of the word "type" that has frequently led to confusion, since, properly speaking, the forest is composed of a number of types as distinct as the western yellow pine type, the eastern white pine type, or any other forest type. In this and other publications of the Forest Service, therefore, the term "woodland forest" will be used in place of "woodland type."

In making the study of Utah juniper, the results of which are given in this circular, the aim was to secure as many data as the time allowed for the investigation would permit, on (1) the silvical characteristics which most influence reproduction, (2) rate of growth, and (3) volume. The study was made in and near the Tusayan National Forest, Ariz. While the data gathered are insufficient as a basis for final conclusions, they should serve, until more detailed information can be had, as a general guide in the management of the Utah juniper type.

DISTRIBUTION.

Utah juniper is one of the most abundant and generally distributed trees from the western foothills of the Wasatch Mountains, in eastern Utah, to southeastern California, and throughout northern and central Arizona, western Colorado, and southern Wyoming. It is distinctly a tree of the high plateau region bordering the desert, growing at altitudes between 4,800 and 7,000 feet, with the best stands between 5,500 and 6,500 feet. It attains its best individual development and grows in heaviest stand in Coconino County, Ariz., directly west of the railroad from Williams to the Grand Canyon.

NOTE.—The work on volume and yield is by Walter Mulford; all other parts are by Frank J. Phillips, except as otherwise noted.

CLIMATIC REQUIREMENTS.

Like the other species which go to make up the woodland forests of Arizona and New Mexico, Utah juniper grows in regions where the average annual rainfall is from 14 to 18 inches, usually nearer

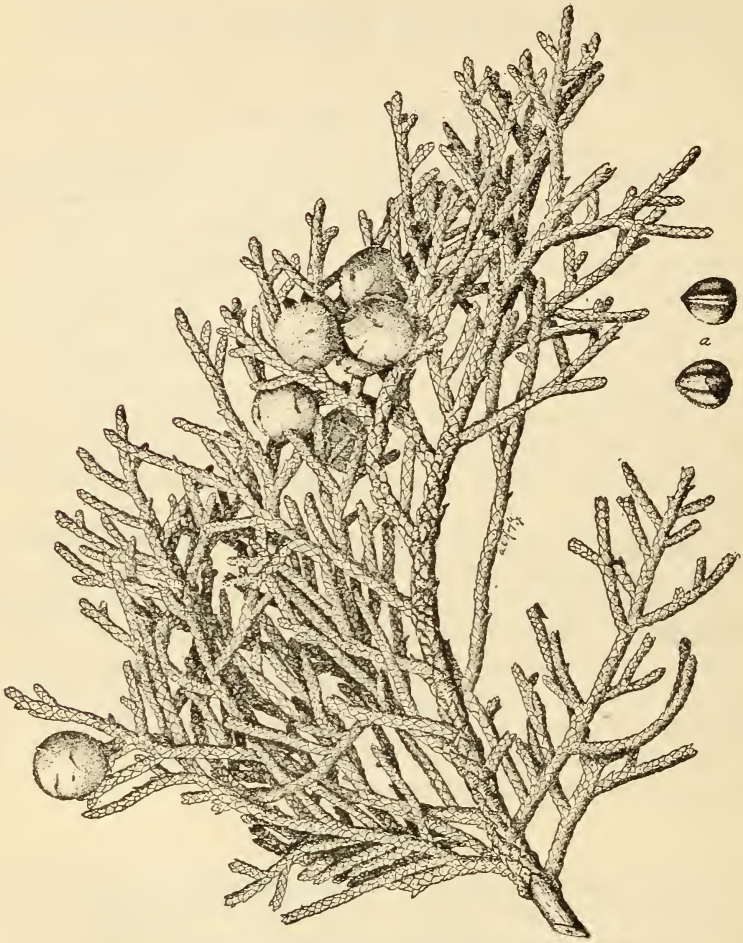

FIG. 1.—Utah juniper—leaves, fruit, and seed.

the first, with a minimum of from 9 to 10 inches and a maximum of about 25 inches. Most of this comes in July and August and is usually torrential.

BOTANICAL CHARACTERISTICS.[1]

The leaves of Utah juniper are minute, sharp, scale-like, and pale yellowish-green; generally without a pit (gland) on the back; mostly in alternately opposite pairs, closely overlapping each other in 4

[1] From Forest Service Bulletin, Forest Trees of the Pacific Slope, by George B. Sudworth.

rows on the slender, stiff-looking twigs; sometimes in 6 rows with three leaves at a point. The leaves of vigorous leading shoots are much larger and are keenly pointed, while those of seedlings are needle-like. The bark of larger twigs which have shed their leaves is pale reddish-brown and scaly. Ripe berries, matured in the fall of the second year, are covered with a whitish bloom which, when rubbed off, exposes a smooth, red-brown, tough skin. They usually contain one seed (occasionally two), pointed at the end, prominently and sharply angled, and marked nearly to the top by what appears to be scale-like basal covering (the seed scar), to which the thin, sweet pulp is attached. The surface of the berries shows projecting points (ends of minute flower scales). Seed leaves, usually 5 in number, but ranging from 4 to 6, are pointed.

SILVICAL CHARACTERISTICS.

SITE REQUIREMENTS AND ASSOCIATED SPECIES.

In the region studied, pure stands of Utah juniper are found on rolling slopes and hills with a very fine adobe soil, thickly studded with large malpais (basaltic lava) rocks. Interspersed with the trees are many individuals or groups of buckbrush (*Cowania mexicana*), probably indicating the presence of a large amount of lime. The ground cover consists of many annuals and perennials, the most common a coarse bunch grass. The trees attain their best development in the canyons, reaching a diameter of 3 feet and a height of from 30 to 35 feet.

Near the desert pure stands of Utah juniper are usually confined to hilltops covered with malpais outcrops, or to adobe valleys where there appears to be more than the usual amount of moisture. It also grows in the malpais canyons leading out to the desert, usually with a few specimens of *Morus celtidifolia* and *Celtis reticulata* and numerous shrubs. On all the more unfavorable sites the limits of the stand are sharply defined by surrounding adobe clays of fine texture.

On limestone formations about Grand Canyon, covered with shallow soil, Utah juniper is mixed with piñon. Two sample plots of one-half acre each showed an average of 68 per cent piñon and 32 per cent Utah juniper. While this is the condition on the high plateau which slopes to the southwest, on that sloping toward the east various-sized groups of Utah juniper and piñon are interspersed among other groups of western yellow pine and Gambel oak.

In the region west of Cedar Glade, Utah juniper is found in pure stands between approximate elevations of 5,100 and 5,500 feet, but from 300 to 800 feet higher up it grows in mixture with single-leaf piñon (*Pinus monophylla*). Here, though the latter seems to be

confined to sandstone and limestone areas, juniper grows on malpais as well. The two species have been found in close mixture elsewhere in Arizona, usually with a small amount of Rocky Mountain red cedar also present. Near Ash Fork and at Gleed a few specimens of alligator juniper were observed in mixture, and at Mount Picacho a few New Mexican locusts. The canyons, naturally, present the greatest variety of trees and shrubs in mixture with Utah juniper. In the canyons about Gleed and Puntenny *Quercus chrysolepis* is the most common of these.

From the desert to regions of pure western yellow pine, then, the character of the stand of Utah juniper may be classified as follows:

(*a*) Widely scattered individuals encroaching on the desert.

(*b*) Island stands encroaching on the desert, usually on malpais outcrops.

(*c*) Pure stands over large areas, chiefly on mixed malpais and adobe sites.

(*d*) In close mixture with piñon (*Pinus edulis*), or more rarely with *Pinus monophylla*.

(*e*) In groups with piñon, interspersed with other groups of western yellow pine and Gambel oak.

Near the desert the species gains foothold through reproduction beneath the crowns of early scattered trees, resulting in even a more marked grouping than on better sites. In pure stands the trees occur in small, evenly distributed groups, exhibiting wide variation in yield, which, however, appears comparatively uniform when taken for large areas. The two classes of mixed stands form transitional stages between the pure stands of Utah juniper in the Aubrey Cliffs region and the nearly pure stands of western yellow pine in the San Francisco Peaks.

STEM AND CROWN.

The tendency to fork is more pronounced with Utah juniper than with any other prominent species of the woodland forest. Forking occurs usually at the surface of the ground, though sometimes at from 1 to 2 feet above. Mature trees rarely have a regular leader or a clear length of more than 3 or 4 feet. The growth of the entire tree is, in fact, exceedingly crooked.

When young the tree is roughly conical in form, and during middle age distinctly globular. In the veteran stage the crown is ragged and stag-headed, with many dead twigs at the ends of growing shoots. At middle age the crown is about as broad as long, while in old trees the width is slightly greater than the height.

On exposed sites, such as malpais outcrops and hilltops, the tree shows the effect of prevailing southwest winds by leaning slightly to the northeast. The tendency was especially evident in the "island"

stands between Gleed and Mount Picacho, and to a less degree on hilltops near the Grand Canyon. On poor sites near Mount Picacho the branches were somewhat longer on the northeast side of the trees than to windward, and the crowns were from 5 to 25 feet broader than long.

ROOT SYSTEM.

The most marked characteristics of the root system of Utah juniper seedlings, as observed during a study on the malpais site at Gleed, are the exceptionally long taproots on even the smallest plants, and the presence of mychoriza. The latter seem most abundant from 1.5 to 10 or more inches below ground, and on seedlings with the thriftiest growth. Seedling roots are distinguished by the deep maroon color of the inner bark, by the slight taper of the laterals, and by the presence of only a moderate number of root hairs. The taproot tends to grow straight down to the rock substratum, at a depth of from 18 to 36 inches, and when that is reached to turn abruptly at right angles. Table 1 shows the length of taproot for different ages and heights of seedlings.

TABLE 1.—*Length of taproot in seedlings of different ages and heights.*

Age.	Height.	Length of taproot.
Years.	*Inches.*	*Inches.*
1	1.3	10.5
2	3.3	15.4
3	6.3	19.4
4	9.7	21.8
5	13.2	23.9
6	16.7	26.0
7	19.8	26.0

Only one healthy mature tree was observed to have been uprooted by the wind. A number of dead trees, however, had been blown down, and these furnished data on the root systems of old trees. Though the largest root almost invariably goes straight down to the substratum, the root system as a whole is distinctly lateral. The roots, usually from three to six in number, vary in diameter from 4 to 15 inches at their junction with the trunk. On the usual malpais formation the root system is seldom more than 2 feet deep, extending to the edge of the crown, or, on exposed sites, to from 10 to 20 feet beyond.

REPRODUCTION.

Utah juniper, like most of the junipers, is a prolific seeder in open stands. The best seed crops are nearly always produced on the poorer sites, where the trees are usually loaded with berries, sometimes as much as 2 or 3 bushels. On better sites, even in the same locality,

only a few trees bear seed, and these rarely more than from 1 to 3 quarts. Some seed may be secured from one locality or another every year, but nowhere does the species fruit at regular intervals. Most of the berries are eaten by birds, predatory animals, and rodents.

In pure stands reproduction occurs chiefly under the crowns of large mature trees. Results from typical sample plots of 1 acre each are given in Table 2. The figures in the last four columns are for seedlings in partial shade.

TABLE 2.—*Proportion of seedlings in open and under partial shade.*

Total.	Number seedlings in open.	Number of seedlings under partial shade.	Per cent on north.	Per cent on south.	Per cent on east.	Per cent on west.
172	40	132	27	34	24	15
230	51	179	31	30	18	21

Reproduction under shade on the areas studied was confined very largely to a limited zone directly beneath the outer edge of the crown. Under trees with a crown radius up to 12 feet, 76 per cent of the reproduction occurred in a zone the inner limit of which was 2 feet within and the outer limit 1 foot beyond the crown edge. Outside of this zone was 13 per cent of the total reproduction, while between the inner edge of the zone and the trunk of the tree was 11 per cent. Where the tree crowns had an average radius of from 13 to 17 feet, 81 per cent of the reproduction occurred in a zone with an inner limit 2 feet inside and an outer limit 2 feet beyond the crown edge, the greater breadth of zone being probably due to a more irregular crown. Outside this zone occurred 12 per cent of the seedlings and inside only 7 per cent.

INJURIES.

FUNGI AND MISTLETOE.[1]

Utah juniper in the vicinity of Gleed is badly affected with rot caused by a species of fungus, *Fomes* (*Pyropolyporus*) *texanus*, which attacks the heartwood of older living trees, gaining entrance through wounds and fire scars. This appears to be worse at the base of the tree, and often extends into the roots to a depth of from 1 to 2 feet or more beneath the surface. A sample count of 100 trees on a hilltop and of another hundred in an arroyo approximately 100 feet lower in elevation gave results shown in Table 3.

[1] The greater part of the material under this head is contributed by Dr. George G. Hedgcock, Office of Investigations in Forest Pathology, Bureau of Plant Industry.

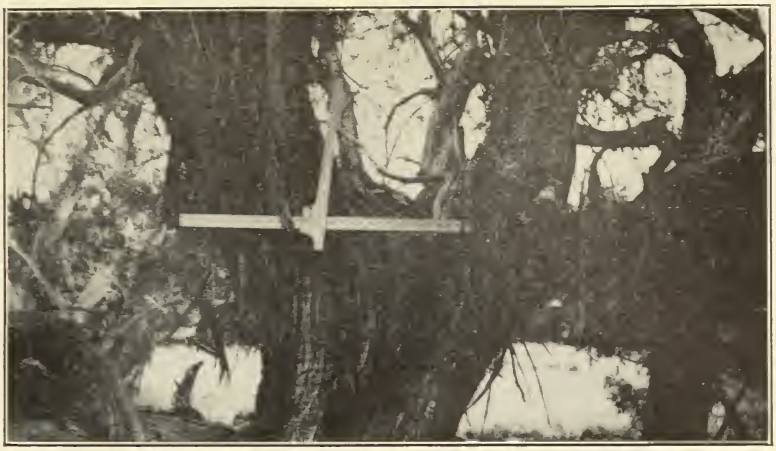

FIG. 1.—A UTAH JUNIPER FORKING AT BREASTHEIGHT. THE BUTT DIAMETER IS 21 INCHES.

FIG. 2.—VIRGIN STAND OF UTAH JUNIPER.

FIG. 3.—IRREGULARITY OF UTAH JUNIPER CORDWOOD STICKS.

TABLE 3.—*Percentage of trees affected by rot.*

Locality.	Sound.	Slight butt rot.	Severe butt rot.	Total butt rot.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Hill	77	12	11	23
Arroyo	69	13	18	31

The apparent relative soundness on hill sites, though suggestive, is based on too little data to be conclusive.

A species of rust, *Gymnosporangium kernianum* Bethel, attacks the young twigs of some trees, causing the formation of dense "witches' brooms." This stunts the growth of the trees attacked, but rarely kills them. A second species, *Gymnosporangium gracilens* (Peck) Kern and Bethel, attacks the limbs, occasionally forming fusiform swellings. The limbs attacked often die, and sometimes the trees also. A third species, *Gymnosporangium nelsoni* Arth., attacks the twigs, forming woody, globose galls, sometimes densely aggregated, and, when numerous, stunting the trees. A fourth species, *Gymnosporangium inconspicuum* Kern, attacks the younger twigs between the leaves, causing the latter to turn yellow and injuring the trees whenever the attack is severe.

In many localities, especially on poorer soils and exposed slopes and ridges, Utah juniper is attacked by the mistletoe *Phoradendron juniperum* Engelm., the seeds of which adhere to the younger twigs, upon which they germinate, and the roots penetrate the bark and secure a hold in the cambium. After a few years a large dense cluster of the mistletoe is formed on the limb, which, deprived of sufficient nutriment beyond the point of attack, finally dies. In extreme cases as many as 50 mistletoe plants form on a single tree, and by depriving so many limbs of nutrition bring about its death by starvation.

FIRE.

Though in seasons of drought severe fires have occurred in the woodland forest during March and April, the fire danger is greatest in May and June. Surface fires are the most common, but crown fires sometimes occur. In a mixed stand near Grand Canyon the different species suffered in the following degree, the most affected first:

Piñon ..... *Pinus edulis.*
Western yellow pine ..... *Pinus ponderosa.*
Utah juniper ..... *Juniperus utahensis.*

Gambel oak (*Quercus gambelii*) suffers nearly as much as piñon of equal size, but its excellent sprouting capacity enables it to renew the stand. In immediate damage buckbrush (*Cowania mexicana*) suffered less than the Gambel oak.

SHEEP AND CATTLE.

Where grass is plentiful and the range grazed moderately, reproduction suffers little damage from sheep and cattle. But in bad years, in fenced private pastures or along traveled routes between the summer and winter ranges, the reproduction often suffers, especially from sheep. On three sample plots taken near Gleed the first, situated immediately south of a watering place where grazing was severe, showed that 93 per cent of the young trees had been injured by sheep; the second, taken 80 rods to the south of the dam, showed 73.7 per cent injured; and the third, taken about 3 miles northwest of Gleed, 53.4 per cent. These counts were made on trees less than 6 feet tall. With some of these injury had consisted in loss of leaders, though this rarely occurs after the tree has reached a height of 3½ feet, and usually not after 2½ feet. Reproduction protected by brush showed far less injury than that in the open. On cut-over areas, where brush had been scattered over the seedlings, only 15 per cent showed injury, while in the open 81 per cent had been grazed back. These counts included seedlings up to 3 feet tall.

GROWTH.

In the study of growth, which was confined to the malpais formation north of Gleed, the problem of age determination was a difficult one. Stumps of mature trees, one-half hour after cutting, would show seasoning checks, which rapidly increased in number and size for an hour or two, and then gradually for the next two days. The seasoning process also rendered the rings in the heartwood less distinct. Chiseling the sawed stumps immediately after felling, moistening the freshly chiseled surface, and counting the rings as soon as possible, gave the best results.

Utah juniper presents other difficulties in accurate ring counting. In many cases the spring wood and summer wood are defined by two distinct lines rather than by the usual zones of tissue of varying density. These distinct lines are likely to be false rings, more than ordinarily distinct, and in every case were so regarded. Every tree examined showed split [1] rings, which seem to be common to many woodland species. Often these divided gradually, the split going nearly around the stem; in other cases the split was very abrupt, nearly encircling the stem; in still others several splits occurred in the same ring; while in a very few cases double splits were found.

[1] From studies made on this species and other more rapid-growing ones, it would seem that split rings are in most cases due to the advanced growth of especially thrifty branches, since on small trees they often occur in succession in the same radius as some thrifty branch.

In order to trace rings for some distance on each side, a segment, varying from one-fifth to one-twentieth of the cross-section area, was chiseled on all trees, and occasionally ring counts were made on opposite sides of the tree to serve as a check.

In seedling analysis, trouble was also given by crescent-shaped areas of tissue of slightly darker or lighter shade than normal, which give a spiral appearance to the rings as seen in cross section. Dried seedlings often gave somewhat better general results than green ones, and counts made at the top of the root and within 1 inch from the ground were occasionally better than counts at the ground surface. A complete analysis often required an average age between sections one inch or more above and below the desired section rather than a determination at the exact point. In all cases the current year's growth was determined by leader growth rather than by ring counts. Where seedlings occurred in litter one inch or more in depth, the start of the growing point was considered to be at the bottom of the litter.

Seedlings were classified into those growing in the open and in shade, and those injured by grazing and uninjured. Table 4 gives the height.

TABLE 4.—*Height growth of Utah juniper seedlings.*

Age.	In the open.		In shade.		Age.	In the open.		In shade.	
	Uninjured.	Injured by grazing.	Uninjured.	Injured by grazing.		Uninjured.	Injured by grazing.	Uninjured.	Injured by grazing.
Years.	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Years.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*
1	1.3	.....	1.1	.....	21	.....	.....	31.5	16.0
2	3.3	.....	2.4	.....	22	.....	.....	33.0	16.7
3	6.3	3.6	3.6	.....	23	.....	.....	34.5	17.4
4	9.7	5.7	4.9	3.8	24	.....	.....	36.0	18.1
5	13.2	8.1	6.3	5.0	25	.....	.....	37.5	18.8
6	16.7	10.9	7.7	6.1	26	.....	.....	39.0	19.7
7	19.8	13.8	9.1	7.3	27	.....	.....	40.4	20.6
8	22.7	17.0	10.6	8.4	28	.....	.....	41.8	21.5
9	25.1	19.8	12.1	9.3	29	.....	.....	43.2	22.4
10	27.2	22.2	13.6	10.2	30	.....	.....	44.6	23.3
11	29.1	24.2	15.2	10.9	31	.....	.....	.....	24.2
12	30.9	25.8	16.8	11.6	32	.....	.....	.....	25.1
13	32.2	27.4	18.4	12.2	33	.....	.....	.....	25.8
14	33.5	28.9	20.0	12.6	34	.....	.....	.....	26.6
15	34.1	30.4	21.7	13.0	35	.....	.....	.....	27.5
16	35.7	31.9	23.4	13.4	36	.....	.....	.....	28.4
17	36.7	33.4	25.1	13.9	37	.....	.....	.....	29.4
18	.....	.....	26.7	14.4	38	.....	.....	.....	30.3
19	.....	.....	28.4	14.9	39	.....	.....	.....	31.2
20	.....	.....	30.0	15.4	40	.....	.....	.....	32.0

In selecting large trees for measurement, care was taken to choose only those for which all conditions of growth, except light, were as far as possible the same. In Table 5 the trees are classified as grown in the open and in partial shade.

TABLE 5.—*Growth of Utah juniper in open and under shade.*

Age.	Diameter 1 foot above ground.		Height.		Age.	Diameter 1 foot above ground.		Height.	
	Grown in open.	Grown in partial shade.	Grown in open.	Grown in partial shade.		Grown in open.	Grown in partial shade.	Grown in open.	Grown in partial shade.
Years.	*Inches.*	*Inches.*	*Feet.*	*Feet.*	*Years.*	*Inches.*	*Inches.*	*Feet.*	*Feet.*
10	0.6	0.40	2.1	1.3	120	7.95	6.25	15.3	14.2
20	1.2	.85	3.9	2.7	130	8.6	6.8	15.8	14.8
30	1.8	1.3	5.7	4.1	140	9.25	7.3	16.2	15.4
40	2.45	1.8	7.4	5.4	150	9.85	7.8	16.6	16.0
50	3.1	2.3	9.1	6.7	160	10.4	8.25	17.1	16.5
60	3.8	2.85	10.5	8.0	170	10.95	8.65	17.6	17.0
70	4.5	3.4	11.7	9.2	180	11.45	9.05	18.0	17.5
80	5.2	3.95	12.7	10.4	190	11.95	9.45	18.5	18.0
90	5.9	4.55	13.5	11.5	200	12.4	9.85	18.9	18.5
100	6.6	5.15	14.3	12.3	210	12.85	10.25	19.4	18.9
110	7.3	5.7	14.8	13.4					

Table 5 shows that the effect of shade on both height and diameter growth, but especially the former, was small. This does not mean, however, that Utah juniper is tolerant, but rather that the shade of the mother tree is scanty. It also brings out clearly the remarkably slow growth of the species, which reaches a diameter of only 12.85 inches and a height of only 19.4 feet in 210 years.

The great care necessary in the selection of both seedlings and mature trees for measurement makes the bases for Tables 4 and 5 somewhat inadequate. Both tables are, however, as accurate as existing conditions would permit.

VOLUME.

CONSTRUCTION AND USE OF VOLUME TABLES.

Utah juniper's irregular form makes accurate determination of volume exceedingly difficult. Its tendency to divide into two or more stems at or near the ground prevents the use of breastheight as the point at which to measure diameter. The reference diameter selected, therefore, is that outside the bark 1 foot above the mineral soil. Even this is not altogether satisfactory, since the irregular shape of the butt, often accentuated by irregularities due to root swelling and by ridges formed by low branches, makes exact measurement of the diameter difficult, while, even if accurate measurement is possible, variation in number and size of stems above the point of measurement brings about irregularities in volume between trees of the same butt diameter and height. Yet notwithstanding these drawbacks, the butt diameter, as that selected will be termed, seemed the only possible basis on which to compute volume.

The forking habit of Utah juniper made it desirable in measuring volume to consider each of the larger stems in a several-stemmed tree as a separate tree. However, it was necessary to adopt certain

FIG. 2.—A THREE-STEMMED TREE.

FIG. 1.—A TWO-STEMMED UTAH JUNIPER CONSIDERED AS A SINGLE TREE. SMALLER STEM IS LESS THAN 8 INCHES IN DIAMETER.

arbitrary rules in respect to what constituted a separate stem. To be considered as such, it was stipulated that a separate stem of a several-stemmed tree must divide from the trunk at some point between the mineral soil and 1 foot above it, the latter limit to apply to the center of its junction with the trunk, and must have a butt diameter of not less than 8 inches. Stems which separated from the main trunk below the mineral soil were considered as separate trees, no matter what their diameter. Stems which divided from the main trunk at a point more than 1 foot above the mineral soil and those with a butt diameter of less than 8 inches which separated from it within 1 foot of the ground, were considered as parts of the larger stems and their volumes not computed separately. A tree with two or more stems branching above the mineral soil and within 1 foot of the ground, all less than 8 inches in diameter, was considered as a single tree having a diameter equal to that of the largest stem. Any tree with a single stem, however bushy and irregular in form, was considered as a single tree.

In measuring height, the actual length of a leaning tree or separate stem was taken, not the vertical distance of its top above the ground. Separate stems often diverge at so wide an angle that the top of one may be only 6 feet above the ground, though its actual length is 10 feet.

The possibility of error in a comparison of the volume of a single-stem tree with that of a separate stem of a forked tree led to the preparation of separate volume tables for the two classes. The difference between the two tables proved, however, to be both slight and irregular, and they were therefore combined into one.

Accurate volumes in cordwood for Utah juniper are also difficult to obtain owing to the great variation in volume between cordwood sticks of the same middle diameter. Almost any stick from Utah juniper is likely to be exceedingly crooked, as well as irregular in cross section, while usually there are so many small branches to be trimmed that stubs are left on the sticks, which prevent close piling.

Because of the sources of inaccuracy mentioned, volume tables for Utah juniper can at best be only approximate. Applied to single or to only a few trees, or in small cordwood sales, there is likelihood of serious error. Accuracy will increase, however, with the number of trees.

Tables 6 and 7 give volumes for Utah juniper in cubic feet and cords, respectively. The measurements on which the tables are based were made in two places near Ash Fork, Ariz., on medium sites. In applying the tables it will be necessary, of course, to follow strictly the methods of classifying stems and of measuring height used in their preparation. If, however, a large proportion of the trees in a stand divide within 1 foot of the ground into stems, most

of which are less than 8 inches in diameter, the rule to disregard such stems should not hold. Instead, each of the small stems should be considered as a separate tree and its volume determined from Table 6, or else from Table 9. The first method is quicker, but less accurate, since the values obtained will probably be too high.

In using the volume tables it will be necessary to learn to estimate both height and butt diameter, instead of actually measuring them, since the inconvenience entailed by doing the latter with a low-branching tree like the Utah juniper is great. In determining the point 1 foot above the ground on a side stem the estimate or measurement should follow the main stem to the center of the junction and then continue out on the fork.

Although the volume tables are for round wood, they will apply as well where large sticks are split. If nearly all the wood is split, the tables will tend to be conservative.

VOLUME IN CUBIC FEET AND CORDS.

Volume in cordwood was obtained by dividing the volume in cubic feet, computed on the basis of middle diameter outside bark and length, of each stick cut from a tree by 62, the average number of cubic feet per cord. This converting factor was obtained from measurements of approximately 62 cords, in about two-thirds of which the larger sticks were split and in the remainder none of the sticks. The average number of sticks per cord was, in the first case, 176 and in the second 141. The average diameter of the sticks was about 4 inches. Since the converting factor, 62, is based on average size trees, the table, when applied to very small trees, will give values too low and when applied to very large trees too high. The inaccuracies are not great, however, even in the case of a single tree, and will tend to offset each other in an estimate of a number of trees.

TABLE 6.—*Volume of cordwood in stem and branches, in cubic feet.*

Diameter 1 foot above ground.	Height in feet.			Diameter 1 foot above ground.	Height in feet.		
	10	15	20		10	15	20
	Volume solid contents in stem and branches, cubic feet.				Volume solid contents in stem and branches, cubic feet.		
Inches.				*Inches.*			
3	0.2	.....	.....	14	7.0	8.6	10.7
4	.4	.....	.....	15	8.1	10.0	12.2
5	.7	0.8	.....	16	9.3	11.4	13.8
6	1.1	1.3	.....	17	.....	12.8	15.5
7	1.5	1.9	2.4	18	.....	11.4	17.2
8	2.0	2.6	3.2	19	.....	16.0	19.1
9	2.6	3.4	4.3	20	.....	17.6	21.0
10	3.3	4.3	5.4	21	.....	19.4	22.9
11	4.1	5.3	6.6	22	.....	21.2	24.8
12	5.0	6.3	7.9	23	.....	.....	26.7
13	5.9	7.4	9.3				

[1] Based on measurements of 495 trees.

TABLE 7.—*Volume of Utah juniper, stem and branches, in cordwood.*[1]

Diameter 1 foot above ground.	Height in feet.			Diameter 1 foot above ground.	Height in feet.		
	10	15	20		10	15	20
Inches.	*Cords.*	*Cords.*	*Cords.*	*Inches.*	*Cords.*	*Cords.*	*Cords.*
3	0.003	.....	.....	14	0.113	0.139	0.173
4	.006	.....	.....	15	.131	.161	.197
5	.011	0.013	.....	16	.150	.184	.223
6	.018	.021	.....	17	.....	.206	.250
7	.024	.031	0.039	18	.....	.232	.277
8	.032	.042	.052	19	.....	.258	.308
9	.042	.055	.069	20	.....	.284	.339
10	.053	.069	.087	21	.....	.313	.369
11	.066	.085	.106	22	.....	.342	.400
12	.081	.102	.127	23	.....	.....	.430
13	.095	.119	.150				

[1] Basis, 495 trees.

SUPPLEMENTARY TABLES.

Since, with Utah juniper, diameters are measured outside the bark, it was necessary to find the average width of bark for trees of different diameters inside bark 1 foot from the ground. This is shown in Table 8. The difference between widths of bark at the stump and on the upper stems and branches was found to be negligible.

TABLE 8.—*Width of bark in Utah juniper.*

Diameter inside bark.	Average width of bark.
Inches.	*Inch.*
2	0.2
3– 5	.3
6–12	.4
13–21	.5

If the number of trees to be estimated is too few for accurate results to be gotten from the use of Tables 6 and 7, Table 9 may be useful. It is also useful in determining the volumes of trees with many stems under 8 inches in diameter.

TABLE 9.—*Volume of cordwood sticks, Utah juniper.*

Middle diameter outside bark 4-foot sticks.	Volume of stick.	Number of sticks in 1 cord.	Middle diameter outside bark 4-foot sticks.	Volume of stick.	Number of sticks in 1 cord.
Inches.	*Cord.*		*Inches.*	*Cord.*	
3	0.003	333	10	0.035	28
4	.006	166	11	.043	23
5	.009	111	12	.051	20
6	.013	76	13	.059	17
7	.017	59	14	.069	14
8	.023	44	15	.079	13
9	.028	35			

In using the table, count the number of 4-foot sticks in the stem and branches and estimate the diameter outside bark of the sticks of average size. The diameter of each separate stick need not be estimated. With large trees the table will be more accurate if the cordwood sticks are divided into large and small ones, and the average diameter of each class estimated. In any case, however, the table can be used for only a rough estimate of volume, since there is likelihood of error in estimating the average diameter, which, moreover is not an accurate basis on which to compute the average volume of the sticks. Since the converting factor of 62 cubic feet of wood per cord used in constructing the table is based on the average contents of cords containing sticks of all sizes, strictly accurate results will not be obtained when, for example, 4-inch sticks are compared with 14-inch sticks. However, since the average size of all the cordwood sticks cut from a stand of Utah juniper will usually be about the same as that of the sticks used in obtaining the ratio, discrepancies will not be great.

Table 10 may serve as a general guide in determining the number of cordwood sticks to be obtained from average trees of different heights and diameters. It gives the total number of cordwood sticks in the stem and branches above a diameter limit of 2 inches outside the bark at the middle of the stick, or of about 1.5 inches outside the bark at the small end of the stick.

TABLE 10.—*Number of cordwood sticks in trees of different diameters and heights, Utah juniper.*[1]

Diameter 1 foot above ground.	Height.	Number of cordwood sticks.	Diameter 1 foot above ground.	Height.	Number of cordwood sticks.
Inches.	*Feet.*		*Inches.*	*Feet.*	
3	9.0	1.0	15	17.5	16.9
4	10.0	1.6	16	17.9	19.1
5	10.9	2.2	17	18.3	21.3
6	11.8	3.1	18	18.6	23.5
7	12.7	4.0	19	18.9	25.8
8	13.5	5.2	20	19.2	28.1
9	14.3	6.4	21	19.5	30.4
10	15.0	7.8	22	19.8	32.7
11	15.6	9.4	23	20.1	35.0
12	16.1	11.1	24	20.4	37.4
13	16.6	13.0	25	20.6	39.8
14	17.1	14.9	26	20.8	40.2

[1] Based on measurements of 495 trees.

Table 11 gives the number of round posts, 7 feet long, which could have been cut from trees of different diameters in the region studied. The small number of posts per tree, especially in the larger trees, is strikingly shown. The table is derived from estimates, not from posts actually taken out, since all the wood was cut into cordwood. In many places, however, the yield of posts from the larger trees would

probably be much higher than indicated here. The number of posts which can be cut from trees of given sizes varies so in different localities, both because of differences in market requirements and of variation in percentage of stems and branches which will make good posts, that the table can not be relied upon for localities other than those in which the data were gathered.

TABLE 11.—*Utah juniper, yield of posts per tree on the areas studied.*

Diameter 1 foot above ground.	Percentage of trees containing one or more posts.	Average yield of posts per tree (average based only on such trees as contain one or more posts).
Inches.	*Per cent.*	
5- 9	36	1.1
10-14	34	1.5
15-19	31	1.0
20-24	25	1.0

The grading of posts is not uniform. The classification used in the region studied was: A first-class post must be straight, with a top diameter of at least 3½ inches; a second-class post has the same top diameter, but may be somewhat crooked; a third-class post must have a top diameter of at least 2 inches and must be straight. On this basis about 34 per cent of the posts were of class 1; 42 per cent of class 2; and 24 per cent of class 3.

Table 12 should be of help in estimating the cordwood to be derived from stands in which posts are to be cut. To determine this, the approximate amount of cordwood removed in the posts should be deducted from the total cordwood volume. The result will be the amount of cordwood which may be secured in addition to the posts. In constructing the table it was assumed that posts are 7 feet long, and that 1 cord equals 62 cubic feet.

TABLE 12.—*Amount of cordwood removed in posts, Utah juniper.*

Middle diameter of post outside bark.	Amount of cordwood removed in each post.	Approximate number of posts to 1 cord of wood.
Inches.	*Cord.*	
3	0.006	167
4	.010	100
5	.015	67
6	.022	45
7	.030	33
8	.039	26

YIELD.

In order to obtain an idea of the yield of Utah juniper per acre, measurements were made on seven sample plots of 1 acre each, on which the species occurred in practically pure stand. The results are given in Table 13.

TABLE 13.—*Number of trees per acre, Utah juniper.*

Diameter 1 foot above ground.	Number of trees per acre.[1]
Inches.	
3– 4	14
5– 7	28
8–10	31
11–13	23
14–16	15
Over 16	9
Total...	120

[1] Nearest whole number.

Since even the biggest trees of the stand are seldom more than from 15 to 20 feet high, the diameters may seem on the average surprisingly large. This, however, is due to the fact that the reference diameter is near the ground, instead of at breastheight.

The average yield per acre obtained from the seven sample plots was 662 cubic feet, or 10.7 cords (no deduction made for posts). The average yield of posts [1] was 30 of class 1, 24 of class 2, and 17 of class 3; a total of 71.

The variability in yield of Utah juniper was well illustrated when, in spite of the fact that the sample plots were selected as typical of each locality, the cordwood yield varied from 4.4 cords to 27.1 cords, and that in posts from 46 to 117. On private lands the average yield per acre varies from 8 to 20 cords. From 10 to 14 cords is probably a fair average for good stands and 20 cords is considered heavy.

This variability in yield will in all likelihood make it impossible, even with more complete data, to prepare yield tables, based on either type or density of stand, suitable for use on uncruised areas. A better method of estimating the yield of a given area is to estimate the heights and diameters of the trees on circular sample plots, or on strips, and apply the volume table (Table 9).

UTILIZATION.

By far the greater part of the Utah juniper cut is in the form of cordwood for local use. This is transported by wagon or on the backs of burros. Cutting is done, as a rule, by Mexicans, who prefer the ax to the saw, though they are seldom skillful with either. Sometimes

[1] For definition of classes of posts, see page 17.

a stick is cut in two from one side only; sometimes from both sides. The latter method was found to be the less wasteful, though either method wastes much more than the saw. Occasionally a saw is used for cutting the sticks into 4-foot lengths after the tree is felled.

On the National Forest stumps must not exceed 12 inches in height. On private lands the height of stumps ranges from 8 to 30 inches.

MANAGEMENT.

Adequate reproduction of Utah juniper is usually hard to get. What reproduction there is occurs mainly under the edges of tree crowns, and because of this, and the fact that it responds readily to an increase in light, trees selected for cutting should be those which have reproduction beneath them. Cuttings should not ordinarily be heavy, and only small openings should be made in the stand.

Where there is danger of injury from stock, adequate protection can usually be given to young trees by throwing brush over them. This should not be so thick, however, as to exclude light. The fire danger will be increased thereby to some extent, but on the National Forests this is not great.

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